An Aircraft Preference Study on the Application of Vector Maps in U.S. Navy Tactical Aircraft

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Abstract

Cockpit digital map displays have long been considered a good situational awareness (SA) tool for the pilot. However, most cockpit map displays have been limited to display of digitized paper charts and imagery due primarily to limited computational capabilities in tactical aircraft. One significant problem encountered by tactical aircraft pilots is map display clutter. Important mission planning and real-time overlays are often rendered over the map display during flight. The clutter resulting from the combination of these overlays with the underlying map display can lead to reduced situational awareness. Unfortunately, the feature content of digitized paper charts and imagery cannot be altered in these map displays to help alleviate the clutter. Next-generation cockpit map displays will not have the computational limitations of previous systems. Vector map displays can provide for added customization and embedded information within the map and address the problems associated with cluttered map displays. Of course, there are tradeoffs to be made between the potential of added flexibility in the cockpit versus a potentially higher pilot workload. A web-based Vector Map survey was developed to gather Navy and Marine Corps aircrew preference data to evaluate functional aspects of vector maps in the cockpit and in mission planning. The aircrew that responded to the Vector Map survey represented a full cross-section of Navy and Marine Corps Tactical and Rotary Wing platforms, and their associated missions, who currently have or are expected to have a requirement for cockpit Moving Map functionality.

1   Background

Today's U.S. Navy and Marine Corps cockpit digital moving map is primarily driven by three geospatial databases: CADRG (Compressed ARC Digitized Raster Graphics), CIB (Controlled Image Base), and DTED (Digital Terrain Elevation Data). CADRG is the U.S. Department of Defence (DoD) standard digitized paper chart map product. CADRG is a simple scanned, digital representation of a paper chart that encompasses a wide range of specific chart series and equivalent map scales. CIB is the U.S. DoD standard digital imagery product available in 10-, 5-, and 1-meter resolutions. Both CADRG and CIB are "raster" databases (i.e. represent a simple pixel-by-pixel reproduction of a picture). DTED is a similar database in that each element represents an elevation value. There are several fundamental problems associated with using these raster-scanned databases as base-maps for aircraft moving-map systems:

- The source paper charts originally were designed to support a wide variety of users. As such, they are general-purpose, with excessive detail irrelevant to many operations.
- The source charts were never intended to be used in a digital context; scanning, transforming, and compressing chart data can render them nearly illegible.
- The source charts were designed to be stand-alone, and overlaying new mission planning symbols on them often results in a distracting, cluttered display.
- There is inconsistency in colors, symbols, and text among the charts (e.g., foreign chart producers, varying chart ages and standards, etc.). The cartographic variability causes disruptive changes in appearance when crossing chart boundaries or changing between chart series.
- Raster chart data are inflexible. Each pixel is a simple RGB (red, green, blue) value with no spatial information, so it is impossible to either customize or query the map.

Vector maps and, in particular, the Vector Product Format (VPF) produced and distributed by the National Imagery and Mapping Agency (NIMA, 1996), are geospatial databases comprised of point, line, and area features that can be queried and displayed by geospatial location and thematic content (e.g. transportation, vegetation, industry). These databases are fully attributed and conform to international DIGEST standards. The ability to query a map on thematic content can provide the pilot with the ability to selectively add or remove detail from a map based on particular mission needs. Vector maps can solve the problems that are inherently associated with typical raster charts. However, while there is value in the added flexibility to design and customize a vector map, there is also the potential for increased aircrew workload to manage the level of flexibility provided in the cockpit and in mission planning. Customization and workload issues with vector maps were first identified in an NRL study conducted in 1995 to help define the baseline mapping requirements for the Tactical Aircraft Moving Map Capability (TAMMAC) digital map system (Lohrenz, Trenchard, & Myrick, 1997). This survey is a next step in helping to define which types of vector map functions are most desired by aircrew who either currently have or soon will have an integrated cockpit moving map display system.

2   Approach

The Naval Research Laboratory (NRL) developed an internet-based, on-line Vector Map survey to gather U.S. Navy and Marine Corps aircrew preference data to evaluate functional aspects of vector maps in the cockpit and in mission planning. NRL used a similar internet-based survey technique as a lower-cost and less intrusive alternative to one-on-one pilot interviews in a pilot-centered study of aircrew mapping needs for MCM (Mine Counter Measures) and ASW (Anti-Submarine Warfare) missions (Trenchard, et al., 2000). The aircrew that responded to the Vector Map survey represented a full cross-section of U.S. Navy and Marine Corps Tactical and Rotary Wing platforms and their associated missions, who currently have or are expected to soon have a requirement for a cockpit moving map capability.

After a short introduction page to familiarize participants with the purpose and scope of the vector map survey, each participant was instructed to complete a registration page that collected information on familiarity with moving map systems, flight experience, platform and mission information. Information from the registration page was used to develop an aircrew profile by both platform and mission type.

The survey was comprised of five functional vector map demonstration pages and a final rankings page. The demonstration pages allowed each participant to view a preset demo of a particular vector map function and/or interact with the vector map display. Once the function had been demonstrated, the participant was then asked to rate (Table 1) the function for use in both the cockpit and mission planning. In addition to rating each vector map function, a "comments" section was included on each page to allow the participant to add qualitative feedback on the vector map function shown. Finally, the participant was asked to rank the five vector map demonstrations in order of priority for implementation.

Table 1: Vector map ratings scale

5	Extremely Useful
4	Of Considerable Use
3	Of Use
2	Of Limited Use
1	Of No Use

A second part to the survey was comprised of the evaluation of six geospatial content vector map pages. However, this paper will only focus on the vector map functional aspects of the survey.

3   Results

3.1   Aircrew Profile

The platforms and missions that were identified by the aircrew participants are shown in Table 2.

Table 2: Vector map survey participants

Platform	Missions	# Participants
AV-8B	Primary - Air-to-Ground Combat (AGC); Secondary - Air-to-Air Combat (AAC)	25
F/A-18 C/D/E/F	Primary / Secondary – AAC; AGC (tied)	27
H-1 (AH-1W, UH-1N)	Primary – AGC Secondary – Forward Air Controller-Airborne	19
H-60 (SH-60B, SH-60F, HH-60H)	Primary – Anti-Submarine Warfare (ASW) Secondary - Search and Rescue (SAR)	16
Other	Various	7
Total		**94**

3.2   Vector Map Functional Analyses

The following vector map functions were evaluated:

1.   Customize Detail of Map Features [Declutter]
2.   Reorder Vector Layers [Reorder]
3.   Upright Text [Upright Text]
4.   View Map Metadata [Metadata]
5.   Database Query [DB Query]

Declutter demonstrated the ability to customize the detail of map features by thematic and selective feature content. Reorder demonstrated the ability to de-conflict map features by re-ordering the feature content. Upright Text demonstrated the ability to separate layers of vector information to allow text information to remain in a north-up orientation regardless of the orientation of rest of the map, thus providing better text readability of the map. Metadata demonstrated the ability to access detailed map feature attribution (e.g., runway lengths, composition) and data quality (e.g. source, accuracy). DB Query demonstrated an advanced method to quickly declutter a map based upon pre-defined queries on the attribution of map features to customize a vector map display. Figure 1 shows that Declutter attained the highest overall ratings and weighted priority rankings for cockpit implementation.
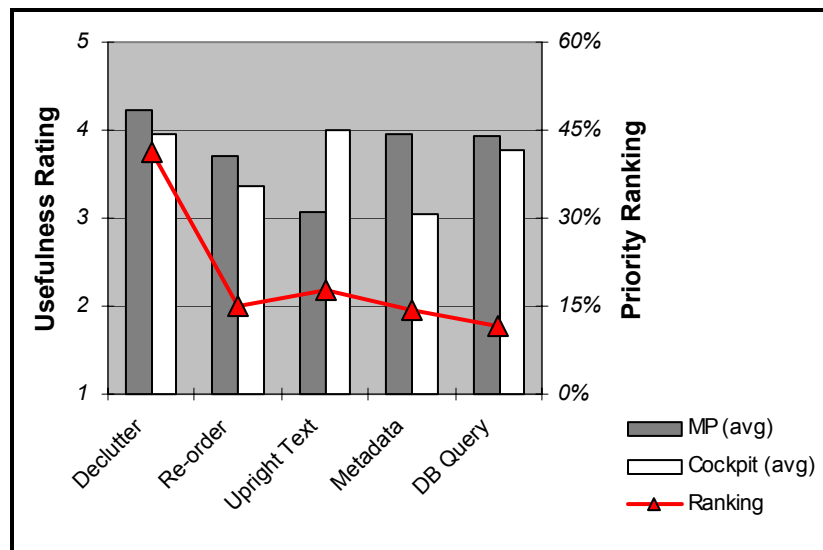

Figure 1: Vector map functional ratings / rankings

Both the AV-8B Harrier and F/A-18 Hornet communities addressed concerns with task prioritization and workload issues in the cockpit relative to the Vector Map functions outlined in the survey. Customizing details of map features and viewing metadata functions would allow them to tailor the map display to minimize task saturation and access specific data if necessary. There was also concern about potential of the upright text function to adversely affect situational awareness. The re-order vector layers and database query functions were seen as potentially task intensive, but the ability to set aircrew profiles during mission planning was highly desired and could mitigate a potential increase in task workload. The ability to interact with the moving map during mission execution was especially desired by the H-1 and H-60 communities. The high priority assigned to customizing map features, reordering vector layers and keeping text upright are consistent with the high priority of map utilization for threat avoidance, terrain avoidance and navigation. Detailed map study during mission planning would reduce the priority for additional map information in flight via the metadata and database query functions. Among all the participants, but particularly those with less flight experience, the database query function was seen as a high priority to assist with determination of available emergency landing airfields. T-test analysis revealed a significant ratings preference toward the customization of map features (declutter) in cockpit implementation for both the AV-8B and H-1 platforms. In mission planning implementation, T-test analyses revealed significant ratings preference toward declutter and database query for both the AV-8B and the H-60, and declutter for the F/A-18. Forced rankings indicated a high preference for declutter for all platforms that participated in the survey. In all demonstrations except the Upright Text demonstration page, all platforms indicated a higher rating preference for implementation in mission planning versus the cockpit. However, all vector map functions had average ratings of at least 3 (of use) or higher for both mission planning and cockpit implementation overall.

4   Conclusions and Recommendations

The ability to declutter a map display was by far the highest ranked vector map function for all platforms for both mission planning and cockpit implementations. This study also suggests that all the vector map functions demonstrated would be very beneficial, particularly in mission planning where more time can be devoted to map study. However, the study suggests there may be benefits to providing a reduced, predefined profile to the aircrew to declutter a map quickly. For example, a pilot may wish to better visualize divert airfields or view real-time sensor, imagery, or mission-specific overlays. Rotary wing platforms (H-1 and H-60) rated and ranked secondary functions of reorder and metadata higher than did fixed-wing fighter aircraft, because rotary aircrew could devote more time to map study and mission re-planning in the cockpit than their fixed wing counterparts. It should be noted that this study was an aircrew preference study and not a performance-based study. Previous work has shown that preference and performance do not necessarily correlate (Merwin & Wickens, 1993). Future work should include a more detailed demonstration of the possible implementations of declutter in a cockpit environment by platform and mission type in a performance-based scenario.

5   Acknowledgements

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Merwin, D., and Wickens, C. (1993). Comparison of eight color and gray scales for displaying continuous 2D data. *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting*.